LAKE CRABAPPLE

REPORT DESCRIPTION

This report is an update on the health of Lake Crabapple based on water quality data collected from 1992 through 2015 by local volunteers and Snohomish County Surface Water Management (SWM) staff. For additional background on the information provided here or to find out more about Lake Crabapple, visit www.lakes.surfacewater.info or call SWM at 425-388-3464.

LAKE DESCRIPTION

Lake Crabapple is a 37-acre lake located north of the Tulalip Reservation in the Seven Lakes area. It is the second in a four-lake chain that begins at Lake Loma and ultimately drains into Tulalip Bay. Lake Crabapple has a maximum depth of 14.9 meters (49 feet) and an average depth of 5.5 meters (18 feet). There is only one identifiable inlet stream flowing into Lake Crabapple, which is located on the eastern shore of the lake. The overall lake watershed, which is the land area that drains to the lake, covers 754 acres, including the watershed of Lake Loma. The watershed contains primarily low to moderate density residential, large rural parcels, and forest. Much of the lake shore is developed with single family homes.

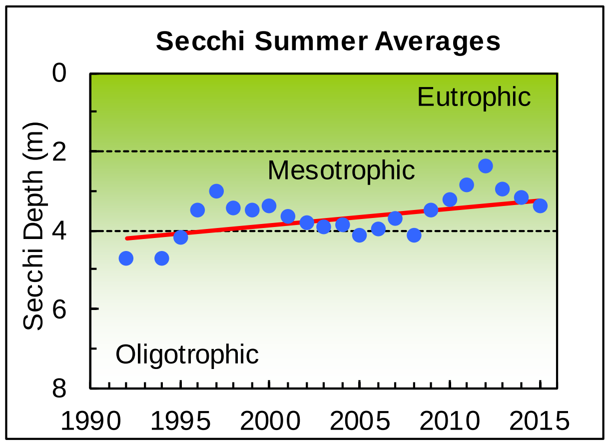
LAKE CONDITIONS

The following graphs illustrate the summer averages and trend lines (shown in red) for water clarity, total phosphorus, and chlorophyll *a* for Lake Crabapple. Please refer to the table at the end of the report for long-term averages and averages and ranges for individual years.

Water Clarity

The water clarity of a lake, measured with a Secchi disk, is a reading of how far one can see into the water. Water clarity is affected by the amount of algae and sediment in the lake, as well as by water color. Lakes with high water clarity usually have low amounts of algae, while lakes with poor water clarity often have excessive amounts of algae.

Water clarity in Lake Crabapple is moderate, with a long-term 1992 - 2015 summer average of 3.6 meters (12 feet). Water clarity has been through an oscillating pattern since the early 1990s. Water clarity steadily declined from 1994 to 1997, but improved slightly from 1998 to 2008. Then, during 2009 - 2012, water clarity declined again. However, 2013 - 2015 summer averages have shown slight improvement. Overall, from 1992 through 2015, there has been a statistically significant trend toward declining water clarity (p=0.03). Changes in water clarity likely reflect the varying levels of algae growth in the lake.



Water Color

The color of lake water affects water clarity and the depths at which algae and plants can grow. In many lakes, the water is naturally brown, orange, or yellow. This darker color comes from dissolved humic compounds from surrounding wetlands and does not harm water quality. Measurements of true water color provide clues to changes in water clarity. True water color is only the color from dissolved materials and not of the color of algae or sediment suspended in the water.

The water color of Lake Crabapple averaged 23 pcu (platinum-cobalt color units) in 2010 – 2011, which indicates a moderate amount of color in the lake water. The color was somewhat darker than the 1994 – 1995 average of 17 pcu. Water color could have some effects on water clarity variations from year to year.

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Temperature

The temperature of lake water changes with the seasons and varies with depth. During spring and summer, the sun warms the upper waters. Because warmer water is less dense, it floats above the cooler, denser water below. The temperature and density differences create distinct layers of water in the lake, and these layers do not mix easily. This process is called stratification and occurs during the warm months. The warm, upper water layer is called the epilimnion. The colder, darker bottom zone is called the hypolimnion. These layers will stay separated until the fall when the upper waters cool, the temperature differences decrease, and the entire lake mixes, or turns over.

The most recent temperature data was taken in May through October of 2014. Temperatures were measured at each meter throughout the Lake Crabapple water column. The temperature data show that by May the upper waters were already 23°F warmer than the lower waters, and the lake maintained strong stratification through October (see graph). This means that there was a large temperature difference between the warm upper waters and the cool bottom waters, and mixing did not occur between these layers. The surface waters reached a temperature peak in July of 77°F (25°C). At the same time, bottom water temperatures saw almost no change, staying about 43°F (6°C). By October, the surface waters were cooling off. As the stratification weakens, the lake water will turn over or mix, and temperatures will become equal from top to bottom. The lake will stay mixed during the winter until springtime, when the upper waters begin to warm again.

Dissolved Oxygen

Oxygen dissolved in the water is essential for life in a lake. Most of the dissolved oxygen comes from the atmosphere. Like temperature, dissolved oxygen levels vary over time and with depth. During the warm months, the upper waters receive oxygen from the atmosphere, but the lower waters cannot be replenished with oxygen because of the separation between water layers. Meanwhile, bacteria in the lake bottom are consuming oxygen as they decompose organic matter. Eventually oxygen is depleted in the bottom waters. Low dissolved oxygen in the bottom waters can lead to a release of nutrients from the lake sediments.

The depth profiles of dissolved oxygen measured in 2014 largely mirrored the temperature profiles seen during that time period (see graph). Oxygen levels were relatively high in the upper waters from May through October. In addition, from May through August, there was a sharp increase in dissolved oxygen levels about 10 feet down in the lake. This indicates vigorous algae growth at that depth which added oxygen to the water. In contrast, throughout the warm stratified period, dissolved oxygen levels in the lower waters were much lower than in the upper waters. During this time, oxygen in the lower waters was consumed by the decomposition of organic material within the lake. Since the lake was strongly stratified, the oxygen was not replenished by the overlying oxygen-rich upper waters or by the atmosphere. In the fall and winter, when the upper waters begins to cool, dissolved oxygen from the atmosphere will mix farther down into the lake. By mid-fall, the lake will be fully mixed and dissolved oxygen levels will again be nearly equal from the top to the bottom of the lake.

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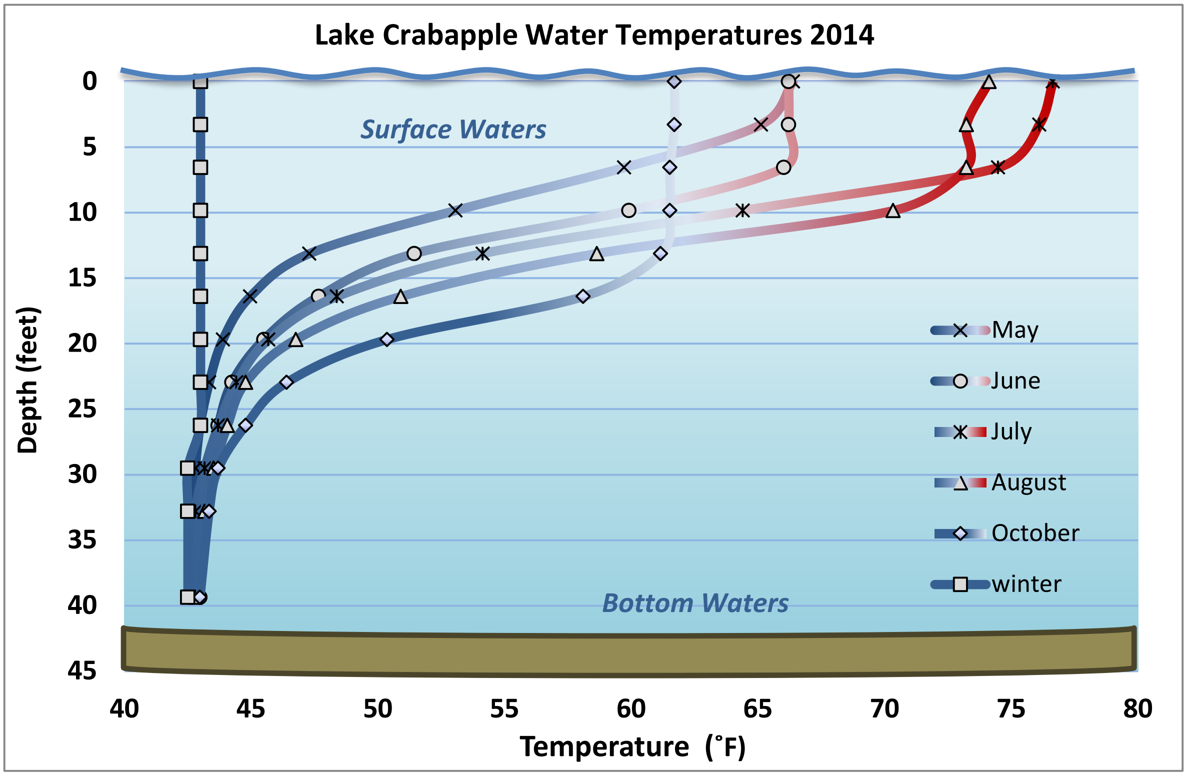

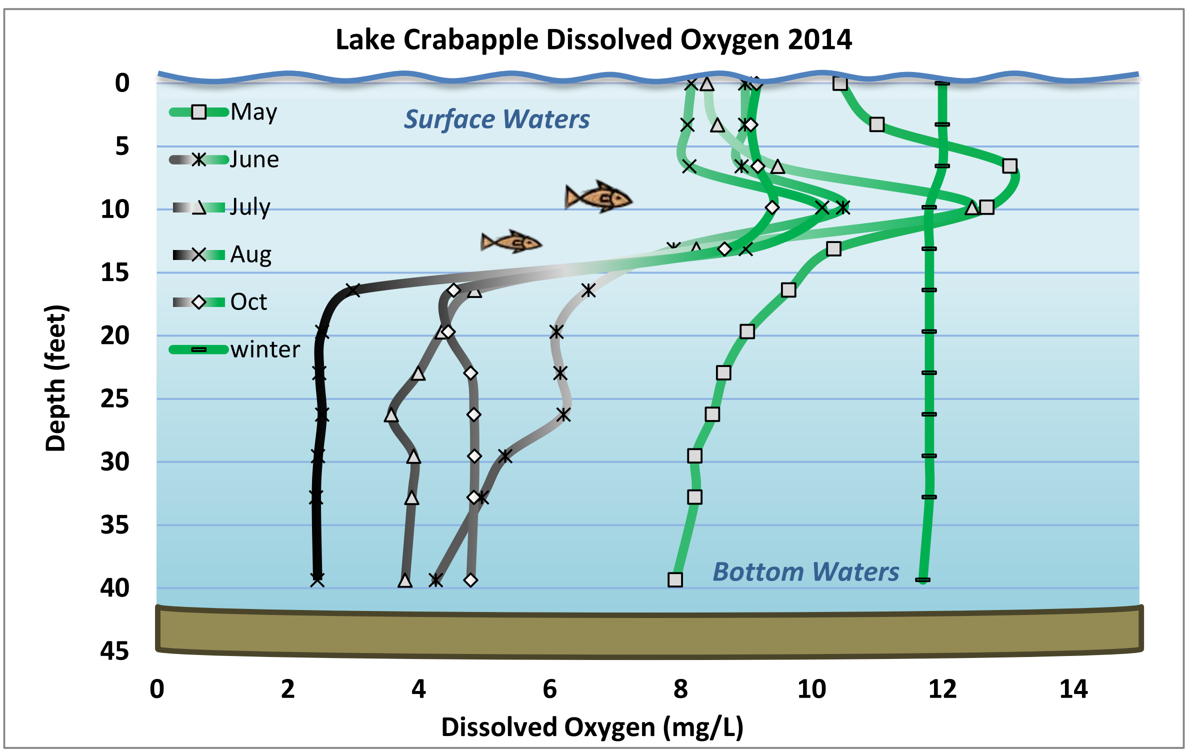

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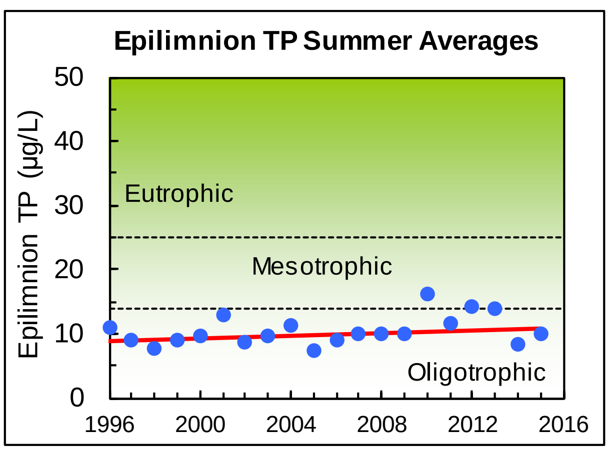
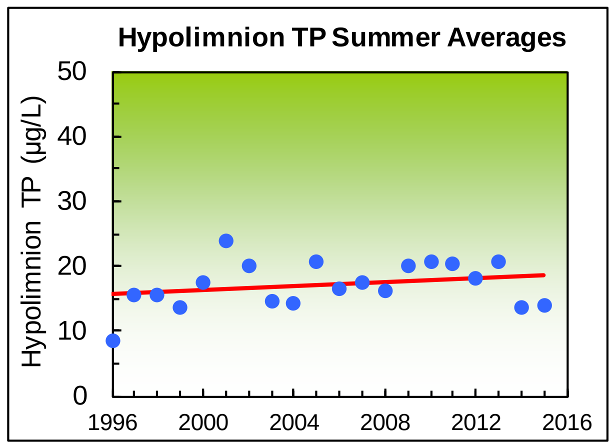
Phosphorus (key nutrient for algae)

Nutrients are essential for the growth of algae, fish, and aquatic plants in a lake. However, too many nutrients, especially phosphorus, can pollute a lake and lead to unpleasant algae growth. Nutrients enter the lake through stormwater runoff or from streams flowing into the lake. Sources of nutrients include fertilizers, pet and animal wastes, poorly-maintained septic systems and erosion from land clearing and construction. Monitoring of phosphorus levels over time helps to identify changes in nutrient pollution.

Total phosphorus concentrations in Lake Crabapple are moderately low. The 1996 – 2015 long-term summer average for the epilimnion (upper waters) is 11 µg/L (micrograms per liter, which is equivalent to parts per billion). The 2010 summer average of 16 µg/L was the highest on record. From 1996 through 2013, there had been a small but statistically significant trend toward increasing phosphorus concentrations in the upper waters. However, the 2014 and 2015 summer averages were low, only 8 - 10 µg/L, so there is no longer evidence of an increasing trend. Any increases in phosphorus can lead to more algae growth in the lake.



The long-term summer phosphorus average in the hypolimnion (bottom waters) is also relatively low at 17 µg/L. However, like the upper waters, phosphorus levels in the bottom waters were steadily increasing through 2013. From 2014 - 2015 the summer average dropped to only 14 µg/L. As a result, there is no longer a statistically significant trend toward higher phosphorus levels. Elevated phosphorus concentrations in the hypolimnion mean that phosphorus is being released from the bottom sediments during the summer period when dissolved oxygen levels drop in the bottom waters. More phosphorus in the bottom waters may eventually lead to more algae growth in the lake.



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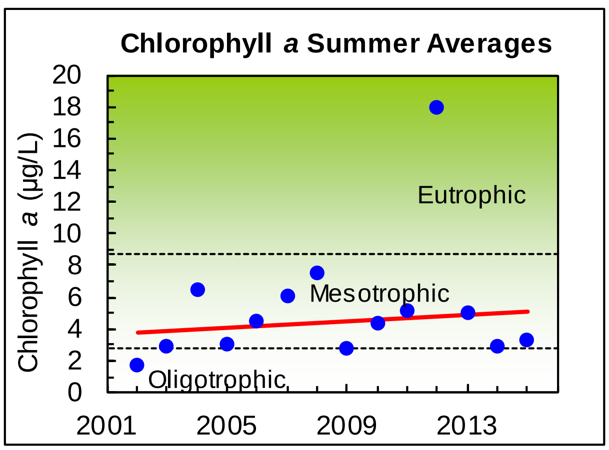
Chlorophyll a (Algae)

Algae are tiny plant-like organisms that are essential for a healthy lake. Fish and other lake life depend on algae as the basis for their food supply. However, excessive growths of algae, called algae blooms, can cloud the water, form unsightly scums, and sometimes release toxins. Excess nutrients, such as phosphorus and nitrogen, are the main cause of nuisance algae growth in a lake. Chlorophyll *a* measurements are one method for tracking the amount of algae in a lake.

Chlorophyll *a* values in Lake Crabapple show moderate algae levels. The 2002 – 2015 long term summer average is 4.5 µg/L. There has been a wide fluctuation of chlorophyll *a* averages from year to year, with the 2012 summer average being the highest on record at 18 µg/L. This was primarily because of one very high measurement in June during an algae bloom.



The variability in summer averages reflects the fact that Lake Crabapple occasionally has periods of high algae growth called blooms. In the spring of 2005, a severe algae bloom turned the lake brown and drastically reduced water clarity. The bloom was *Uroglenopsis*, a type of golden-brown algae that was reported to be blooming at several other lakes in the region. This type of bloom is particularly notable because the algae release a chemical that smells like dead fish as the bloom dissipates. A similar brown algae bloom occurred in the spring and early summer of 2008 and again in the spring of 2013.

Lake Crabapple frequently experiences spikes in algae growth each spring and sometimes in early summer, mostly from diatoms and green algae. The consistent blooms in early spring, coupled with occasionally higher summer chlorophyll *a* readings, could indicate that excess algae may become a future concern in Lake Crabapple. Algae growth may occur in response to the nutrient-rich bottom waters being mixed with the upper waters after the lake turns over in early fall.

Toxic Blue-Green Algae (Cyanobacteria)

Blue-green algae, also called cyanobacteria, are a group of algae capable of producing toxins during periods of high growth, known as blooms. The toxins can cause serious illness in people and pets that come into contact with affected water. Blooms often look like blue or green paint floating on the surface. Lake users should avoid contact with the water and keep pets away from the lake when it is experiencing a blue-green algae bloom. If a bloom has been identified as toxic, the lake will have postings at public access sites.

Since 2005, volunteers and SWM staff have screened algae at Lake Crabapple for potentially toxic blooms. The first documented toxic algae bloom was in December 2015, with Microcystin (a liver toxin) test results above the Washington State Department of Health recreational limit of 6 µg/L.

Screening will continue in 2016 as part of the regular lake monitoring program. Continued monitoring will help alert the public to potential health risks as well as determine the frequency and severity of toxic algae blooms at Lake Crabapple.

Nitrogen (another essential nutrient for algae)

Nitrogen is another important nutrient for plant and algae growth. Similar to phosphorus, lakes with high levels of nitrogen typically have more aquatic plants and algae. In 2014 and 2015, Lake Crabapple had relatively high levels of total nitrogen, with summer averages of 693 µg/L and 513 µg/L respectively. This is consistent with the moderate chlorophyll *a* concentrations measured in the lake.

The relative abundance of nitrogen and phosphorus can also be a useful indicator of lake conditions. This is referred to as the nitrogen to phosphorus ratio or N:P ratio. When lakes have low N:P ratios (typically less than 20), algae growth is often high and harmful blue-green algae blooms may be a problem. Low N:P ratios may also indicate that fertilizers, septic systems, polluted runoff from developed areas, and release of phosphorus from the lake bottom sediments are contributing most of the nutrients to the lake.

In contrast, when lakes have higher N:P ratios (greater than 20), algae growth will be limited by the amount of phosphorus available, and blue-green algae are usually less of a problem. Lake Crabapple had the second highest average N:P ratio of all Snohomish County lakes (N:P=69) because of relatively high nitrogen levels and low phosphorus levels. This helps explain the lack of persistent blue-green algae problems in the lake.

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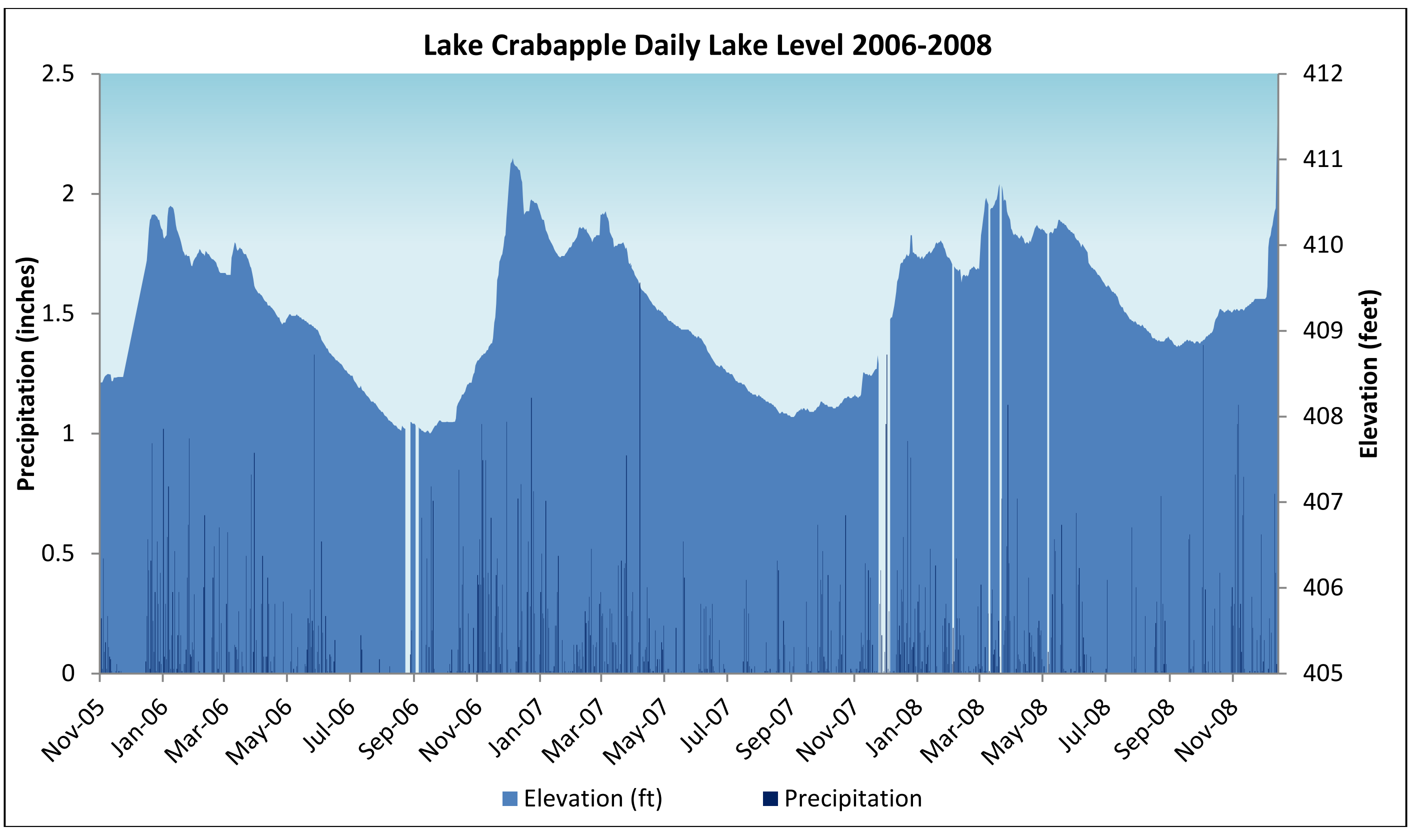
Lake Level

Lake level data tracks the amount of water in the lake and the balance between water coming in by streams, precipitation, groundwater and water leaving by evaporation or outflow. Lake levels in our region are highest in early spring and lowest in late summer and fall. The importance of lake level is to indicate the seasonal effects of the water balance in the lake. In addition to rainfall, lake levels can be affected by sedimentation, surrounding topography, beaver activity, plugged outlets, and the ratio of developed to undeveloped land in the watershed. Paved or impervious surfaces will create faster runoff and quickly rising lake levels during large rain events, while forests, wetlands, and pastures will slow down runoff and limit large rises in lake level

Volunteers collected daily lake levels from November 2005 through the end of 2008 from a lake level gage installed on their dock (see graph). The precipitation data used for graph was recorded Lake Crabapple. The lake levels fluctuated an average of 2.5 annually. Although there was no lake level data collected in 2015 at this gage, the summer of was dry and the lake level dropped quite low. Heavy rains in in the fall resulted in large rises in the lake level.



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SHORELINE CONDITION

The condition of the lake shoreline is important to understanding overall lake health. Frequently, lake shorelines are modified through removal of natural vegetation, the installation of bulkheads or other hardening structures, and/or removal of partially submerged logs and branches. These types of alterations can be harmful to the lake ecosystem because natural shorelines protect the lake from pollution, prevent bank erosion, and provide important habitat for fish and wildlife.

Lake Crabapple has a lower level of shoreline development than many other lakes in the county. Surveys conducted in the mid-90s identified 41 homes bordering the lake. There are also 49 docks present on the lake, covering about 1% of the lake. About 20% of the 1.2 mile shoreline has been armored, mainly in the form of bulkheads (63%) and wood or rock revetments (27%). The zone of vegetation immediately adjacent to the shoreline has been altered even more—only 50% of the native vegetation along the shoreline remains intact. However, there is still a substantial amount of large wood (about 156 pieces) remaining in the lake. These old logs and branches are valuable for fish and wildlife habitat.

The shoreline modifications that have taken place around Lake Crabapple make the lake more susceptible to pollution from the watershed, eliminate the buffer of native vegetation that can filter out pollution, and limit the amount of aquatic habitat available to fish and wildlife. The loss of native vegetation along the shoreline can also lead to shoreline erosion.

SUMMARY

Trophic State

All lakes go through a process of enrichment by nutrients and sediment. In this process, known as eutrophication, nutrients and sediment contribute to the ever-increasing growth of algae and aquatic plants. Over thousands of years, lakes will gradually fill up with organic matter and sediments.

Lakes can be classified by their degree of eutrophication, also known as their trophic state. There are three primary trophic states for lakes—oligotrophic, mesotrophic, and eutrophic—as well as intermediate states. Oligotrophic lakes are usually deep, with clear water, low nutrient concentrations, and few aquatic plants and algae. Mesotrophic lakes are richer in nutrients and produce more algae and aquatic plants. Eutrophic lakes are often shallow and characterized by abundant algae and plants, high nutrient concentrations, limited water clarity, and low dissolved oxygen in the bottom waters.

The trophic state classification of a lake does not necessarily indicate good or bad water quality because eutrophication is a natural process. However, human activities that contribute sediment and excess nutrients to a lake can dramatically accelerate the eutrophication process and result in declining water quality.

Based on the long-term monitoring data, Lake Crabapple may be classified as mesotrophic, with moderate water clarity, relatively low phosphorus concentrations, and low to moderate productivity of plants and algae.

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Condition and Trends

Overall, Lake Crabapple is in good condition. However, the lake is not meeting the water quality target of maintaining stable water clarity. There has been a statistically significant long-term trend toward declining water clarity. In contrast, the lake appears to be meeting the target of maintaining stable phosphorus levels. Although there was some evidence of a small increase in phosphorus levels through 2013, there have been no statistically significant long-term trends toward increasing phosphorus in either the upper and bottom waters. If phosphorus levels do increase in the future, the lake may be at risk of water quality declines. The fluctuating chlorophyll *a* summer averages may be a response to more phosphorus in some years.

In order to protect the water quality of Lake Crabapple, measures to control nutrients in the watershed should be taken. To find out more about the causes and problems of elevated lake nutrient levels and tips to improve lake water quality please visit www.lakes.surfacewater.info.

DATA SUMMARY FOR LAKE CRABAPPLE						
		Water Clarity (Secchi depth	Total Phosphorus (µg/L)		Total Nitrogen (µg/L)	Chlorophyll *a* (µg/L)
Source	**Date**	**in meters)**	**Surface**	**Bottom**	**Surface**	**Surface**
McConnell, et al, 1976	Summer **1973**	2.3 - 5.5 (3.6) *n = 3*	10 - 18 (14) *n = 3*	14 - 15 (15) *n = 3*		1.4 - 2.0 (1.7) *n = 3*
Entranco, 1986	**1983**	2.9 - 4.4 (3.7) *n = 4*	<5 - 7 (6) *n = 5*	8 - 33 (15) *n = 5*		1.8 - 4.6 (3.1) *n = 5*
Volunteer	**1992**	4.6 - 4.9 (4.7) *n = 2*	-	-		-
Volunteer	**1994**	3.8 - 6.0 (4.7) *n = 12*	-	-		1.8 - 3.8 (2.8) *n = 2*
Volunteer	**1995**	3.3 - 5.0 (4.2) *n = 9*	-	-		8.1
Volunteer	**1996**	2.7 - 4.1 (3.5) *n = 10*	9 - 13 (11) *n = 2*	8 - 9 (9) *n = 2*		-
Volunteer	**1997**	2.5 - 3.5 (3.0) *n = 9*	6 - 12 (9) *n = 2*	14 - 17 (16) *n = 2*		-
Volunteer	**1998**	3.0 - 4.5 (3.4) *n = 10*	6 - 10 (8) *n = 4*	15 - 16 (16) *n = 4*		-
Volunteer	**1999**	2.7 - 4.0 (3.5) *n = 10*	8 - 11 (9) *n = 4*	12 - 16 (14) *n = 4*		-
Volunteer	**2000**	2.8 - 4.1 (3.4) *n = 10*	7 - 12 (10) *n = 4*	16 - 19 (18) *n = 4*		-
Volunteer	**2001**	2.6 - 4.8 (3.6) *n = 10*	12 - 14 (13) *n = 4*	18 - 29 (24) *n = 4*		
Volunteer	**2002**	2.6 - 5.0 (3.8) *n = 10*	7 - 11 (9) *n = 4*	15 - 29 (20) *n = 4*		1.1 - 2.7 (1.7) *n = 4*
Volunteer	**2003**	2.6 - 5.5 (3.9) *n = 13*	7 - 12 (10) *n = 4*	14 - 15 (15) *n = 4*		1.6 - 6.4 (2.9) *n = 4*
Volunteer	**2004**	1.8 - 5.4 (3.9) *n = 12*	6 - 19 (11) *n = 4*	13 - 16 (14) *n = 4*		1.1 - 21 (6.5) *n = 4*
Volunteer	**2005**	2.4 - 4.9 (4.1) *n = 12*	5 - 10 (7) *n = 5*	14 - 33 (21) *n = 5*		2.1 - 4.8 (3.0) *n = 5*

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DATA SUMMARY FOR LAKE CRABAPPLE						
		Water Clarity (Secchi depth	**Total Phosphorus (µg/L)**		**Total Nitrogen (µg/L)**	**Chlorophyll *a* (µg/L)**
Source	**Date**	**in meters)**	**Surface**	**Bottom**	**Surface**	**Surface**
Volunteer	**2006**	2.8 - 5.0 (4.0) *n = 12*	6 - 11 (9) *n = 12*	11 - 24 (17) *n = 12*		1.1 - 7.2 (4.5) *n = 6*
Volunteer	**2007**	2.7 - 4.9 (3.7) *n = 12*	5 - 19 (10) *n = 11*	14 - 22 (18) *n = 11*		3.2 - 13 (6.1) *n = 5*
Volunteer	**2008**	2.9 - 5.3 (4.1) *n =12*	6 - 13 (10) *n = 6*	13 - 19 (16) *n = 6*		1.9 - 20 (7.5) *n = 5*
Volunteer	**2009**	3.1 - 4.4 (3.5) *n = 10*	8 - 15 (10) *n = 5*	12 - 24 (20) *n = 5*		2.1 - 4.3 (2.8) *n = 5*
Volunteer	**2010**	2.4 - 3.9 (3.2) *n = 11*	7 - 35 (16) *n = 4*	19 - 24 (21) *n = 3*		2.4 - 5.9 (4.3) *n = 4*
Volunteer	**2011**	1.8 - 3.5 (2.9) *n = 13*	8 - 13 (12) *n = 4*	17 - 28 (20) *n = 4*		3.0 - 8.2 (5.2) *n = 3*
Volunteer	**2012**	1.5 - 3.0 (2.4) *n = 7*	9 - 19 (14) *n = 4*	15 - 23 (18) *n = 4*		0.5 - 61 (18) *n = 4*
Volunteer	**2013**	1.9 - 4.4 (3.0) *n = 8*	6 - 22 (14) *n = 4*	16 - 27 (21) *n = 4*		3.7 - 6.4 (5.1) *n = 4*
Volunteer	**2014**	*2.5 - 3.9* *(3.1)* *n = 11*	*7 - 11* *(8)* *n = 4*	*10 - 17* *(14)* *n = 4*	*435 - 924* *(693)* *n = 4*	*1.9 - 4.3* *(2.9)* *n = 4*
Volunteer	**2015**	2.3 - 4.3 (3.4) *n = 12*	7 - 14 (10) *n = 4*	13 - 15 (14) *n = 4*	361 - 750 (513) *n = 4*	1.3 - 5.6 (3.3) *n = 4*
Long Term Avg		**3.6** **(1992-2015)**	**11** **(1996-2015)**	**17** **(1996-2015)**	**603** **(2014-2015)**	**5.3** **(2002-2015)**
TRENDS		**Decreasing**	**None**	**None**	**NA**	**None**

NOTES

- Table includes summer (May-Oct) data only.
- Each box shows the range on top, followed by summer average in ( ) and number of samples (*n*).
- Total phosphorus data are from samples taken at discrete depths only.
- "Surface" samples are from 1 meter depth and "bottom" samples are from 1-2 meters above the bottom.

[a] Average is influenced by one high TP value.